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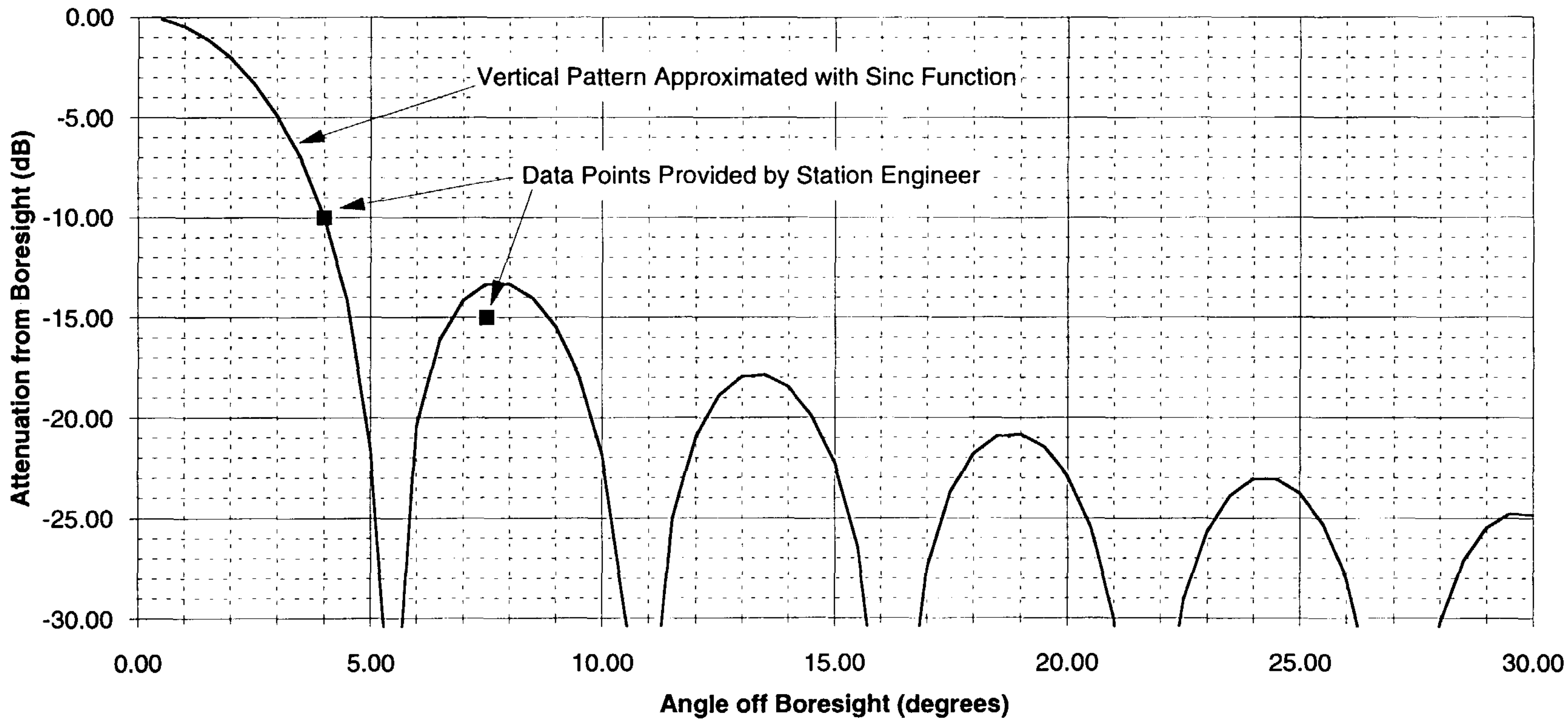
Figure ITFS-4
Vertical Pattern of ITFS Antenna #1 at Grizzly Peak



Globalstar

Figure ITFS-5a
Elevation Angle & Distance from ITFS Transmitter at Grizzly Peak

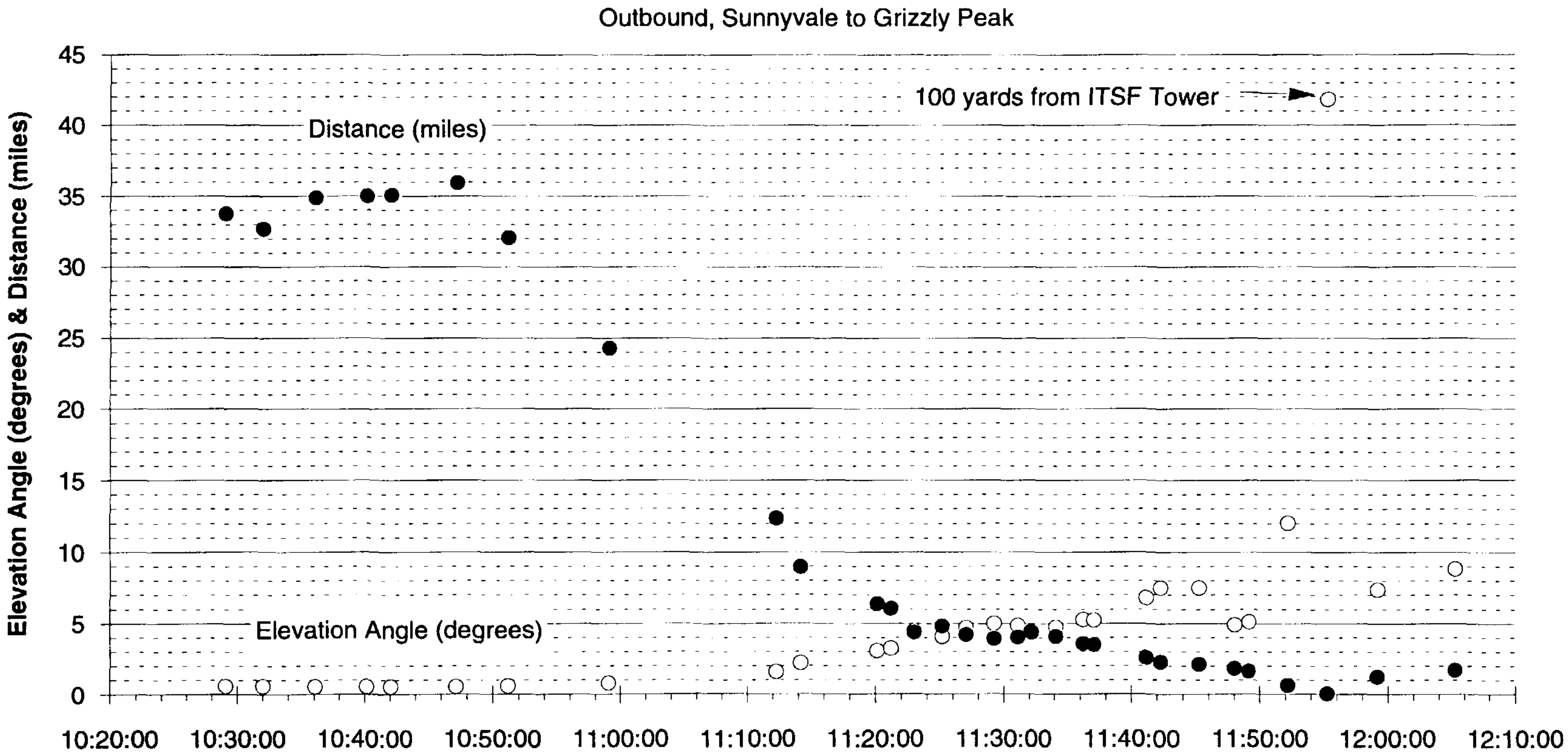


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Figure ITFS-5b
Elevation Angle & Distance from ITFS Transmitter at Grizzly Peak

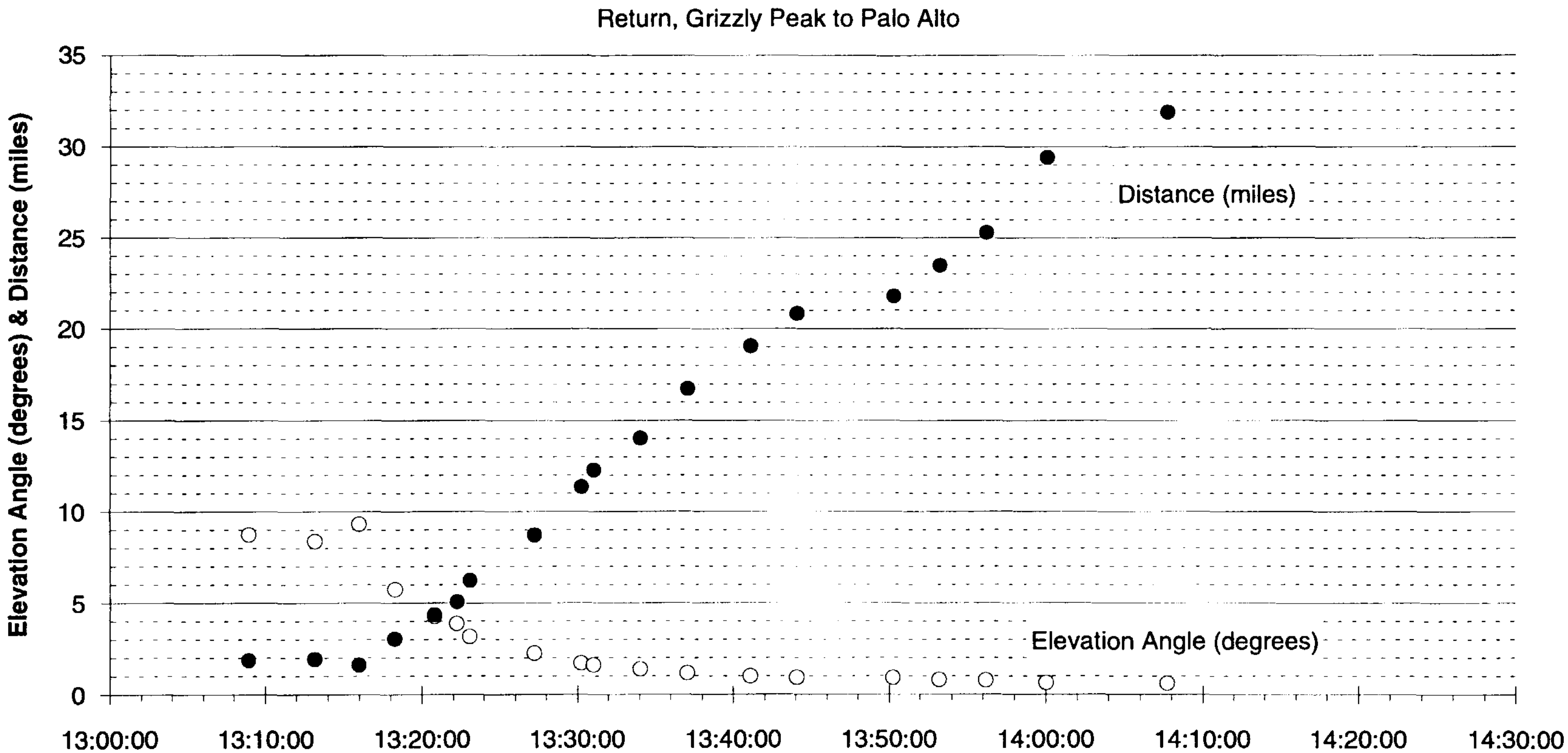

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Figure ITFS-6a
Measured Spectrum Analyzer Levels
ITFS Channel A1 + Highest & Second Highest MSS Channels

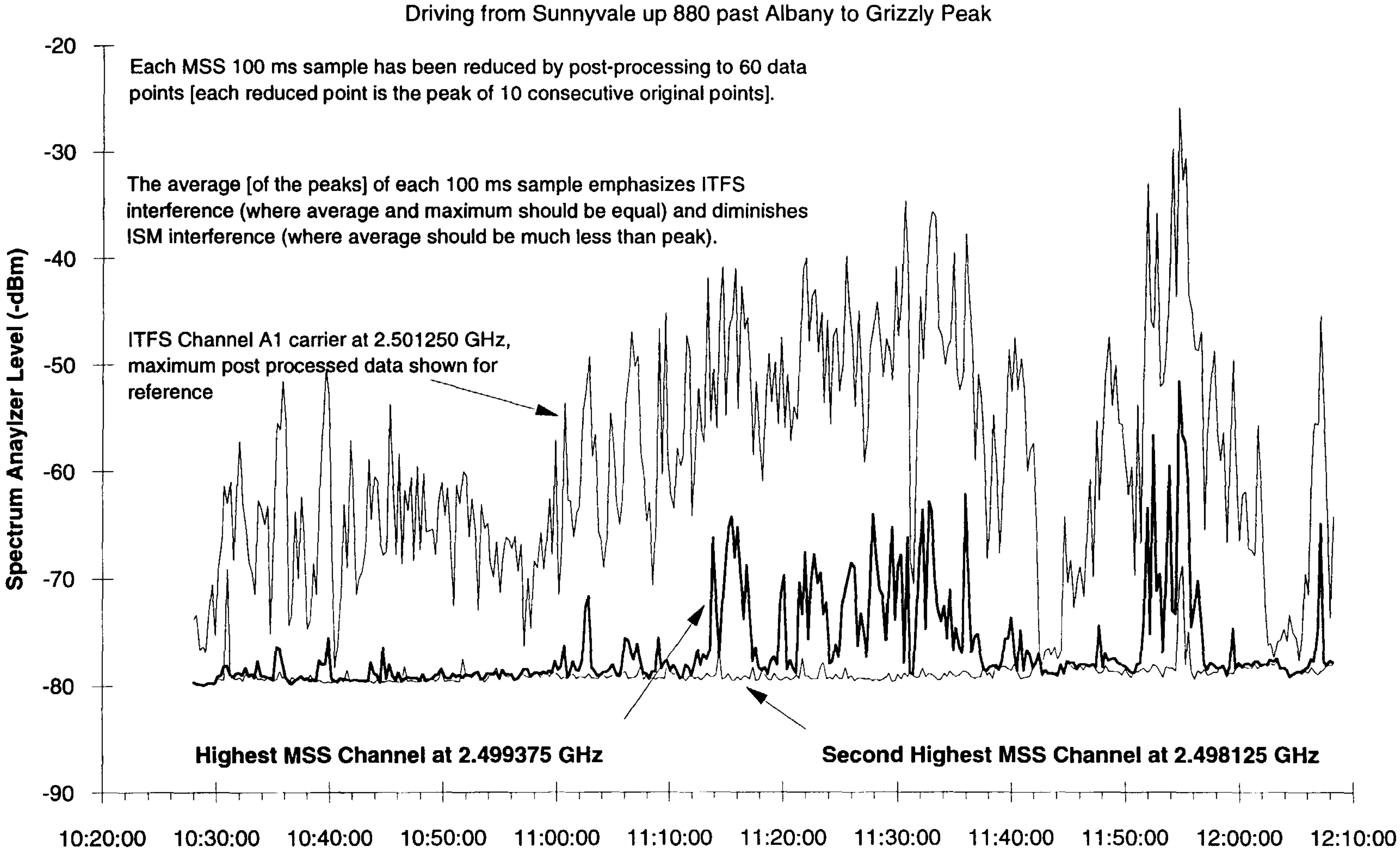

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Figure ITFS-6b
Measured Spectrum Analyzer Levels
ITFS Channel A1 + Highest & Second Highest MSS Channels

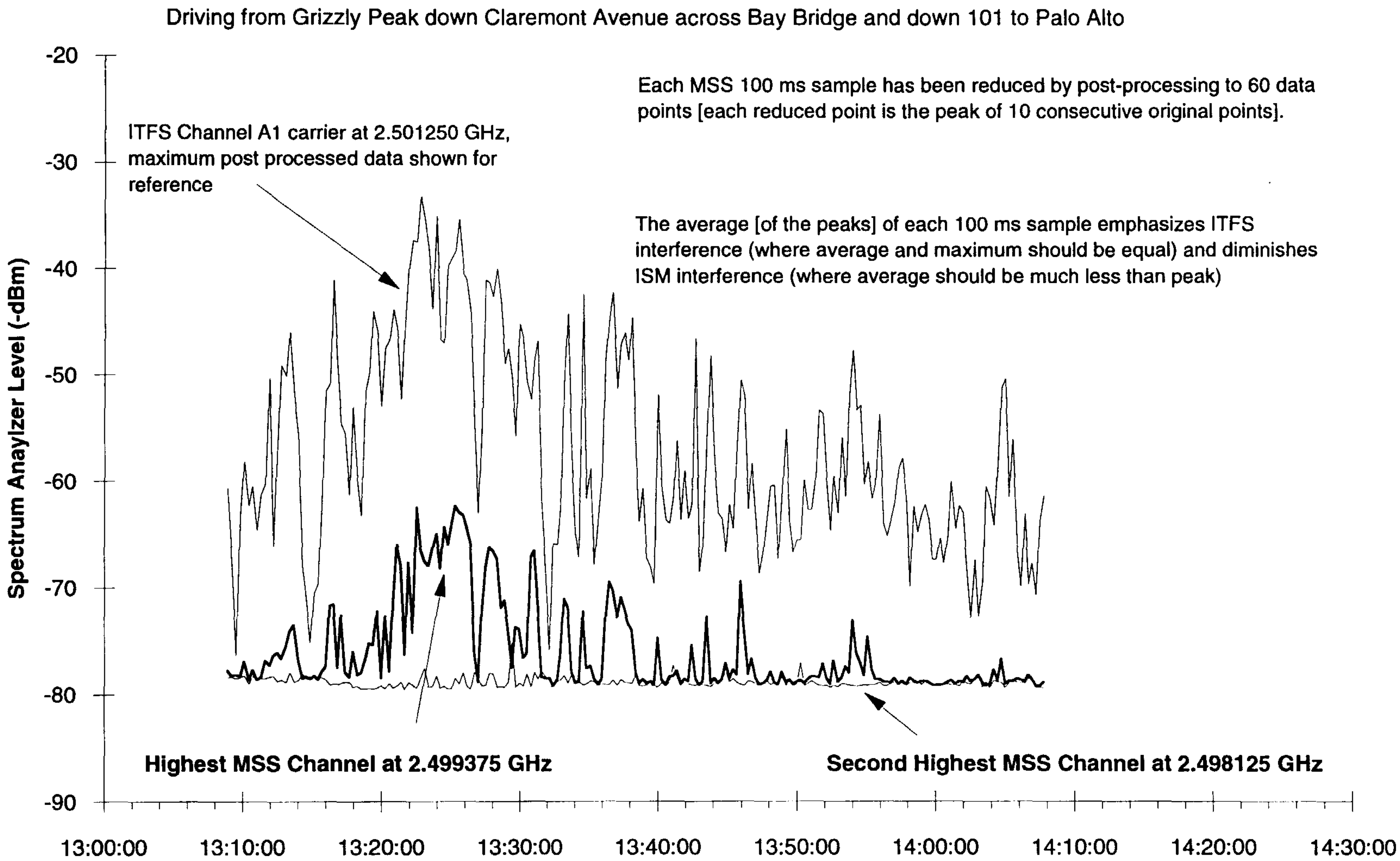

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Figure ITFS-7a
Calculated CDMA Demodulator Input Levels
ITFS Channel A1 + Highest & Second Highest MSS Channels

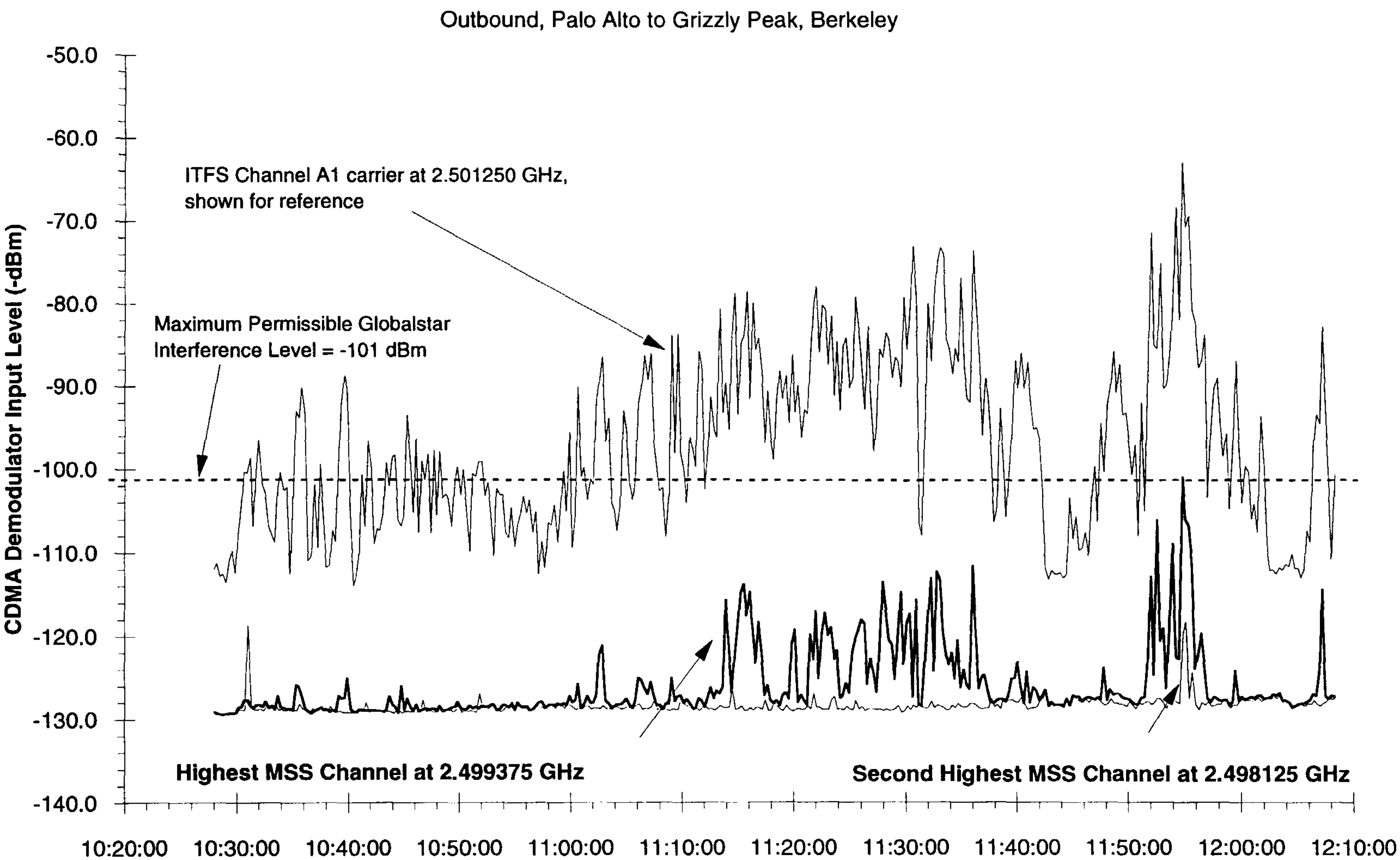

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Figure ITFS-7b
Calculated CDMA Demodulator Input Levels
ITFS Channel A1 + Highest & Second Highest MSS Channels

Return Grizzly Peak, Berkeley to Palo Alto

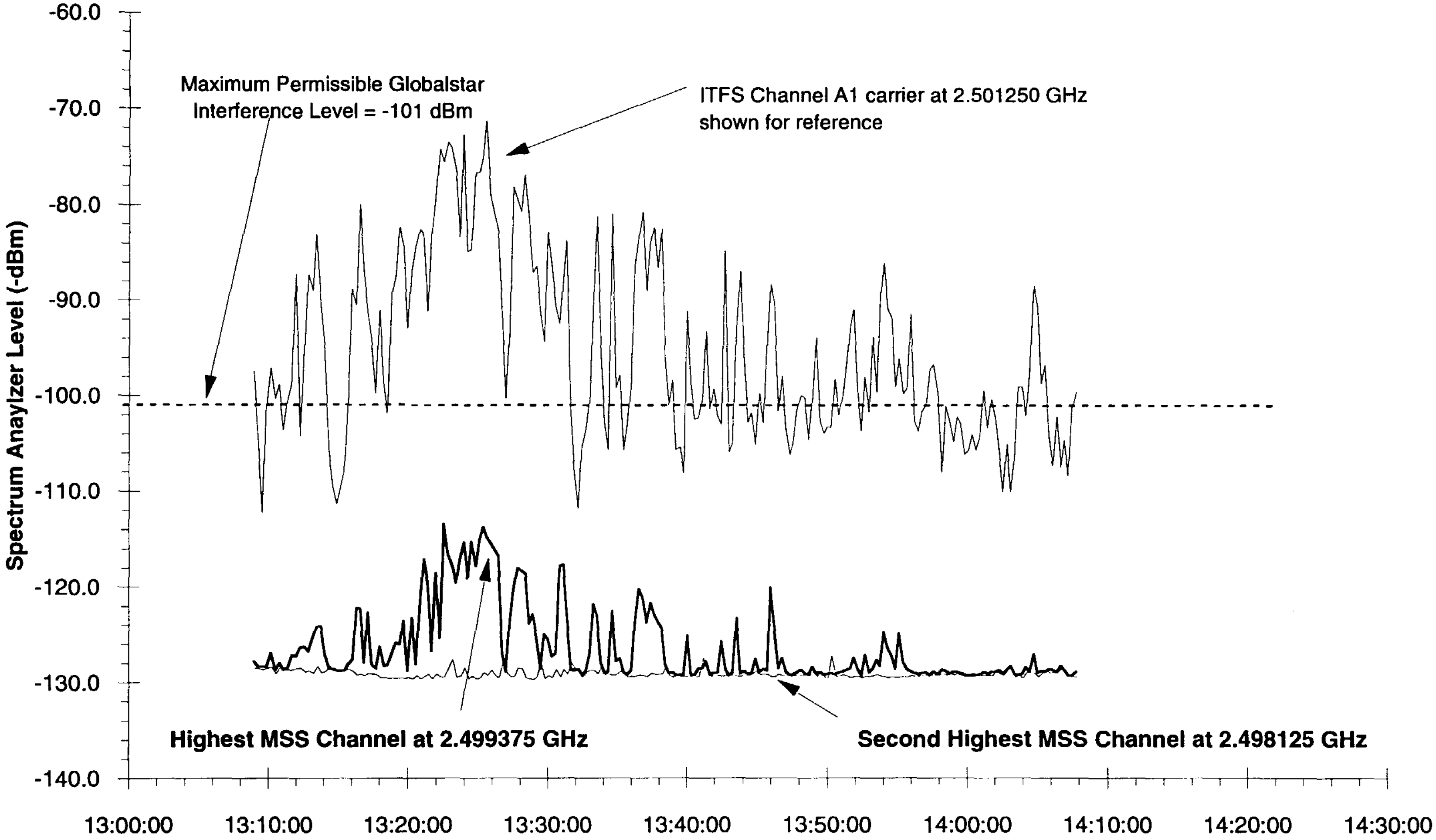

Chart 0315B CDMA T & A1 | Printed 4/26/94 3:16 PM | kap 3/16/94

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ATTACHMENT 4

Field Measurement of ISM Interference in San Francisco Bay Area

Field measurements of ISM interference were made throughout the San Francisco Bay Area. It was determined that field measurements would be required because all the necessary parameters are not available for building an accurate statistical model of the situation.

A van was equipped with (1) a roof-mounted, omni-directional in azimuth antenna, (2) a low-noise preamplifier adjacent to the antenna, (3) a spectrum analyzer as a receiver, and (4) a portable personal computer as a controller and data recorder. Results of the field tests were fed into a laboratory simulation so that evaluations of the situation could be performed in controlled, repeatable tests.

Several test sessions were conducted. The two principle data collections were made on March 15, 1994. The first started from Palo Alto and traveled counter-clockwise around San Francisco Bay, through Oakland, and past Berkeley; the route then circled back north of Berkeley to the base of an ITFS transmitter on Grizzly Peak above Berkeley overlooking the San Francisco Bay Area. The second is the return trip, starting from Berkeley, crossing the San Francisco Bay Bridge, through San Francisco along the Bay to Palo Alto. Measurements were made throughout the San Francisco Bay metropolitan area, which is probably slightly worse than a typical concentration of ISM emitters because of the population restrictions imposed between the San Francisco Bay and its surrounding hills, as well as the possibility of clear over-the-water propagation from multiple emitters across the Bay. Therefore all sequences of March 15 where recorded in an urban ISM environment.

Sequences of time samples where taken while traveling adjacent to urban industrial and residential areas bordering the metropolitan freeways. Each sample was 100 milliseconds in duration (taken within 9 feet at freeway speeds) and the sequence was repeated every 17 seconds (1500 feet at freeway speeds). The spectrum analyzer bandwidth was set to 1 MHz, approximating the wideband CDMA receiver bandwidth.

ISM Band Spectrum Peak Hold Display

The general trend for the ISM interference level is to fall off with increasing frequency above 2450 MHz, making the lowest MSS frequency of 2483.5 MHz typically the worst MSS channel. Therefore ISM interference for the lowest MSS channel was recorded.

Figure ISM-1a "Peak Hold Power Level" shows data records measured throughout a 1-1/2 hours duration for the Palo Alto to Berkeley trip and Figure ISM-1b throughout a 1 hour duration for the return trip from Berkeley to Palo Alto.

The vertical scale of Figure ISM-1 is the level measured at the spectrum analyzer input, while the corresponding received signal level would be approximately 33 dB less than indicated because of the gain of the preamplifier between the (approximately omni-directional) antenna and the spectrum analyzer (e.g., -60 dBm displayed corresponds to -93 dBm received).

The horizontal scale is nearly the entire ISM frequency band, less the lower 10 MHz, but shifted to include 10 MHz of the ITFS band, which adjoins the ISM band at 2500 MHz. A frequency sweep of 2 seconds duration was made every 17 seconds. The receiver resolution bandwidth was 1 MHz. To facilitate plotting, the peak level found in sets of 3 consecutive frequency points was calculated and plotted.

The peak-hold presentation is of the maximum level ever encountered over an extended period of time and at a particular frequency. This type of display masks all lesser occurrences of ISM interference activity during the remaining time of the measurement. Therefore the real ISM interference potential cannot be determined from this type of chart.

(While ITFS Channel A1 appears to produce significant interference in the upper end of the MSS Band, what is being plotted is actually the selectivity of the spectrum analyzer to the ITFS visual carrier 1.25 MHz above 2500 MHz, and the plot does not represent the interference potential of the ITFS spectrum into a MSS MES receiver operating in the highest MSS channel adjacent to 2500 MHz. For a discussion of this effect, see the ITFS report to the NRPM.)

Three-Dimensional Graphs of ISM Interference

Figures ISM-2a through ISM-2e "Lowest MSS Channel, Sequences" are views of the data taken on March 15, 1994. The charts represent consecutive measurement sequences of time sweep of 100 milliseconds made by the spectrum analyzer tuned to the lowest MSS channel.

The first three charts are of 370 sequences recorded during 1-3/4 hours from Palo Alto through Oakland to Berkeley. The next two charts are of 214 sequences recorded during 1 hour on the return trip from Berkeley through San Francisco to Palo Alto. Each sequence is separated by approximately 17 seconds.

Three-Dimensional Graph of Sorted ISM Data

Figure ISM-3 "Lowest MSS Channel, Return Trip Set Sorted" is the 214 return-trip sequences sorted by the maximum (peak) signal encountered in each sweep. This gives a visual picture of the degree of ISM interference. Sorting an entire sequence of records by order of the peak power level encountered provides a statistical picture of the ISM environment.

ISM Peak Measure

Figure ISM-4 "ISM Peaks Measured" is a chart of the peaks measured in each 100 millisecond record after sorting by the peak level measured. These are of the two records made on March 15, 1994, 370 sequences from Palo Alto to Berkeley and 214 sequences returning from Berkeley to Palo Alto.

The maximum peak levels measured on each of the two sequences represent the "peak hold" value which would be displayed in the peak-hold mode of the spectrum analyzer, and it is that value which was illustrated as "peak hold" in the prior NTIA report. These are observed to rare occurrences because after being sorted it is observed the peak power levels fall off rapidly from their maximums.

Histograms of CDMA Receiver Performance With ISM Interference

ISM interference was observed to be pulsed in nature, often with very low duty cycles, but sometimes with a noticeable 60 Hz pattern and higher duty cycles representative of individual microwave ovens. Laboratory measurements with simulated ISM emissions fed into wideband CDMA receivers employing data interleaving have identified the interference mechanism as being primarily dependent on duty cycle (percentage of time above the total noise level). That is, once the ISM interference produces a pulse of level comparable to the total received noise level (system noise plus receiver thermal noise), ISM pulses can damage portions of the received data stream. But with data interleaving, the data can be reconstructed to a degree inversely proportional to the duty cycle of the interference.

Evaluation of the interference potential of the recorded ISM data identified that the ISM interference consists of pulses of magnitude much greater than the intra-pulse level, which was most often below the noise level of the ISM mobile test setup.

The measured sequences were evaluated for the percentage of time that they exceeded a level approximately 10 dB above the total received noise level. The -70 dBm threshold is as measured on the spectrum analyzer and corresponds to a received signal level of -103 dBm when the test setup preamplifier gain of approximately 33.5 dB is included. This is approximately 10 dB above the total received noise level.

The results are shown in Figures ISM-5a and 5b "Histograms of CDMA Receiver Performance With ISM Interference". The duty factors which produced unacceptable interference are those which exceed 20%. From Figure ISM-5a, this results in 0.5% of the 370 or 2 recorded sequences from Palo Alto to Berkeley, and from Figure ISM-5b, this results in 0.5% of the 214 or a single recorded sequence from Berkeley to Palo Alto producing unacceptable performance.

The duty factors which produced noticeable interference but allow serviceable performance are those which exceed 5%. From Figure ISM-5a, this results in 1.4 % of the 370 or 5 recorded sequences from Palo Alto to

Berkeley and from Figure ISM-5b, this results in 1.4% of the 214 or 3 recorded sequences from Berkeley to Palo Alto producing degraded performance.

From laboratory evaluations based on these recorded sequences, of the performance of wideband CDMA reception with data interleaving, it was observed that only the first few records (3 total or 0.5%) produced unacceptable aural signal quality from the CDMA receivers. Another 2% (approximately 14) of the sequences produced degraded but usable signal quality.

ISM Peak Measure Correlated With ISM Interference Potential

Refering back to Figure ISM-4 "ISM Peaks Measured", this indicates that roughly interference levels exceeding -90 dBm are unacceptable and those exceeding -95 dB will probably cause degradation. This is approximately 20 dB and 15 dB respectively above the total received noise level (system noise plus thermal noise) of -112 dBm.

Conclusion

Of the 214 and 370 recorded sequences in the urban environment, only approximately 3 records (0.5%) exceeded a level which would produce call failure. Another (1.5%) would exceed a level which would cause aural signal quality degradation. All other recorded sequences (98%) would produce no noticeable degradation. A rough correlation is noted where those ISM records having the highest peak levels generally produced the worst interference. Peak interference levels up to 20 dB greater than the total received noise level were not observed to produce appreciable aural signal quality degradation.

The ISM emission levels evaluated above are expected to be typical of those within urban environments. Significantly lower levels have been measured in suburban and rural environments. A subsequent campaign of rural environments adjacent to freeways north of San Francisco measured peak levels typically 15 dB lower than those encountered in the urban environment. The interference levels measured are too low to evaluate with respect to duty cycle, producing too few measurable records.

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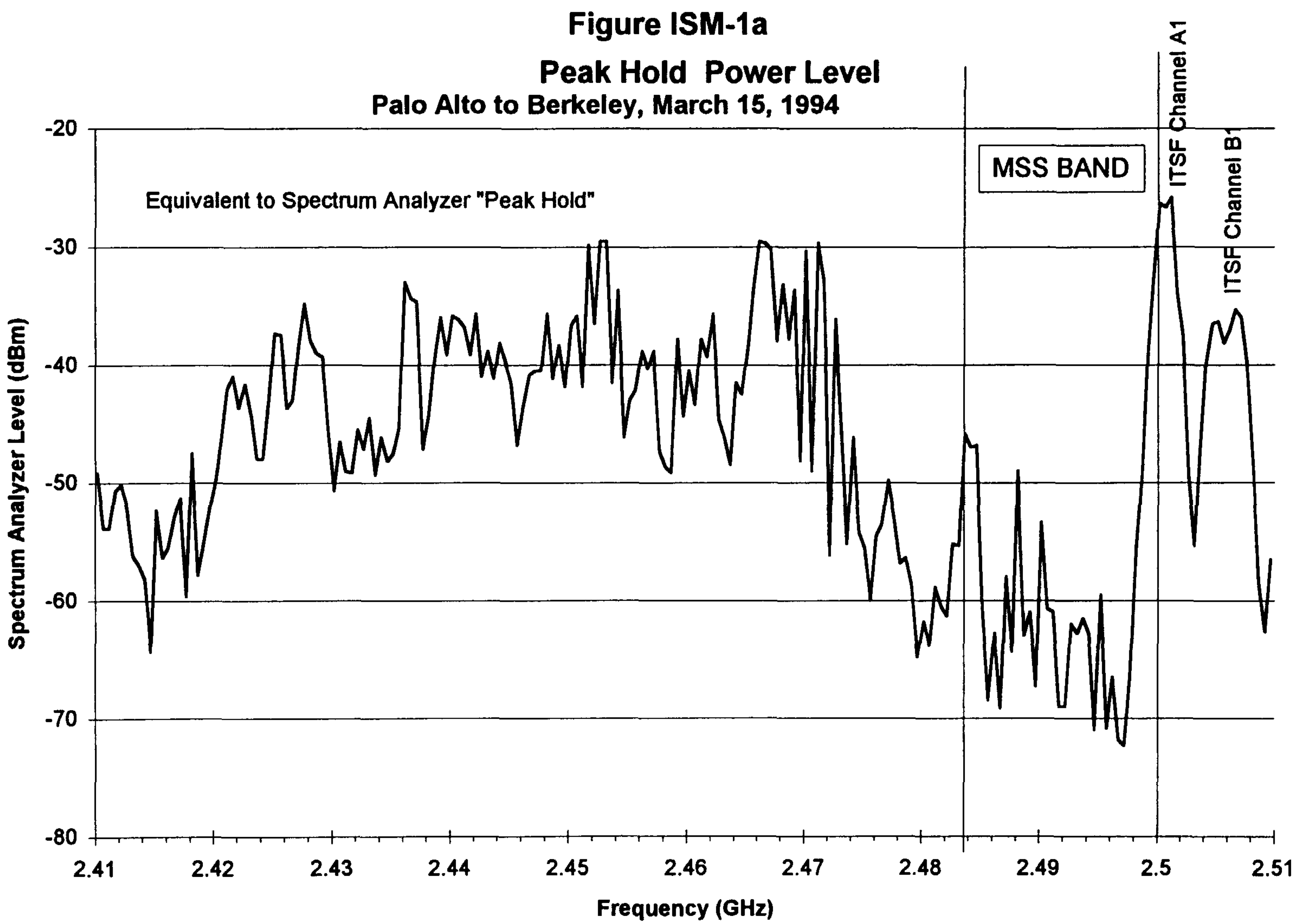

Figure ISM-1a
Peak Hold Power Level
Palo Alto to Berkeley, March 15, 1994
Equivalent to Spectrum Analyzer "Peak Hold"
MSS BAND
ITSF Channel A1
ITSF Channel B1
-20
-30
-40
-50
-60
-70
-80
Spectrum Analyzer Level (dBm)
2.41
2.42
2.43
2.44
2.45
2.46
2.47
2.48
2.49
2.5
2.51
Frequency (GHz)

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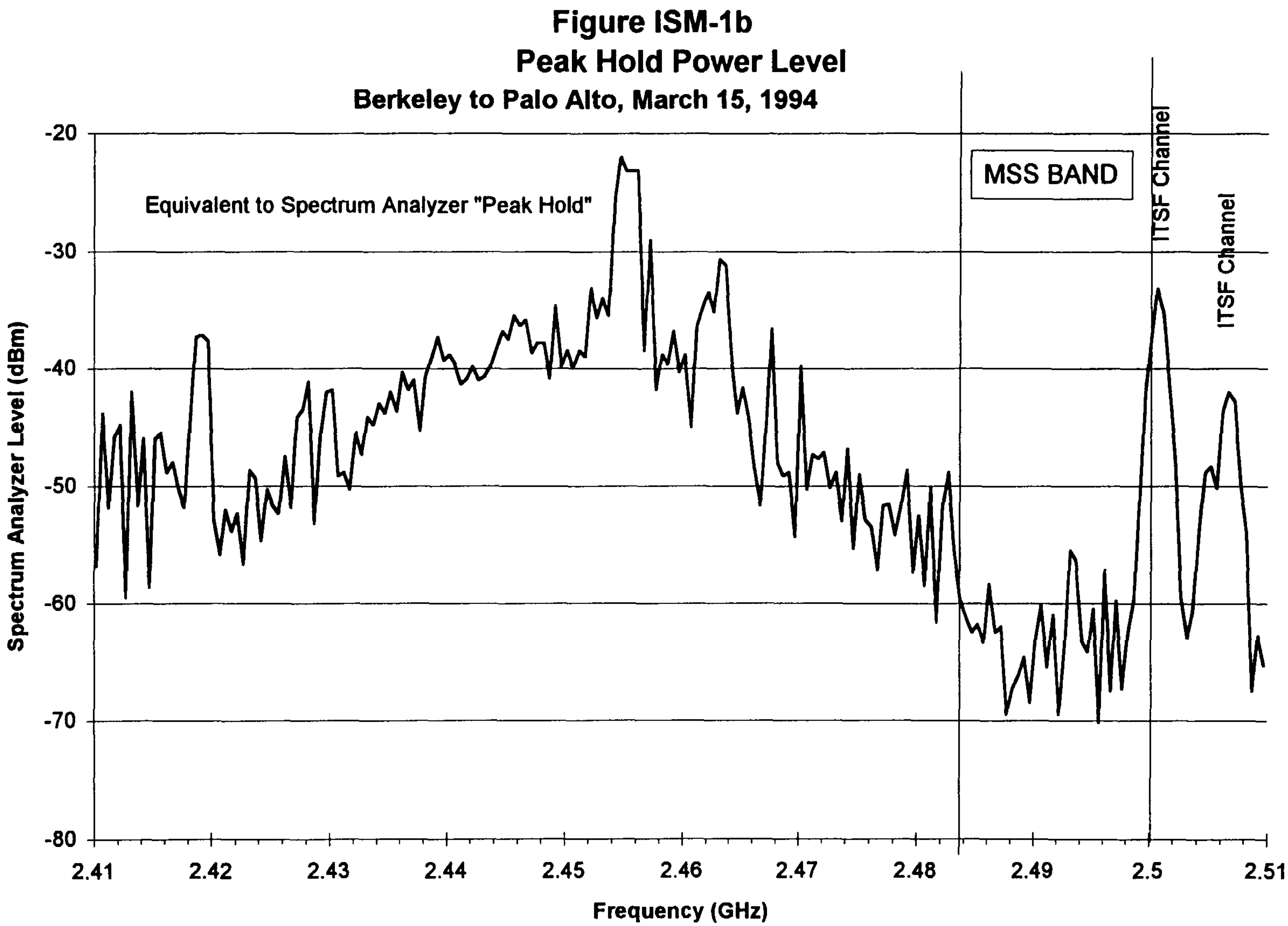


Figure ISM-1b
Peak Hold Power Level
Berkeley to Palo Alto, March 15, 1994
Equivalent to Spectrum Analyzer "Peak Hold"
MSS BAND
ITSF Channel
ITSF Channel
-20
-30
-40
-50
-60
-70
-80
Spectrum Analyzer Level (dBm)
2.41
2.42
2.43
2.44
2.45
2.46
2.47
2.48
2.49
2.5
2.51
Frequency (GHz)

Figure ISM-2a

Lowest MSS Channel

Sequences 1-125

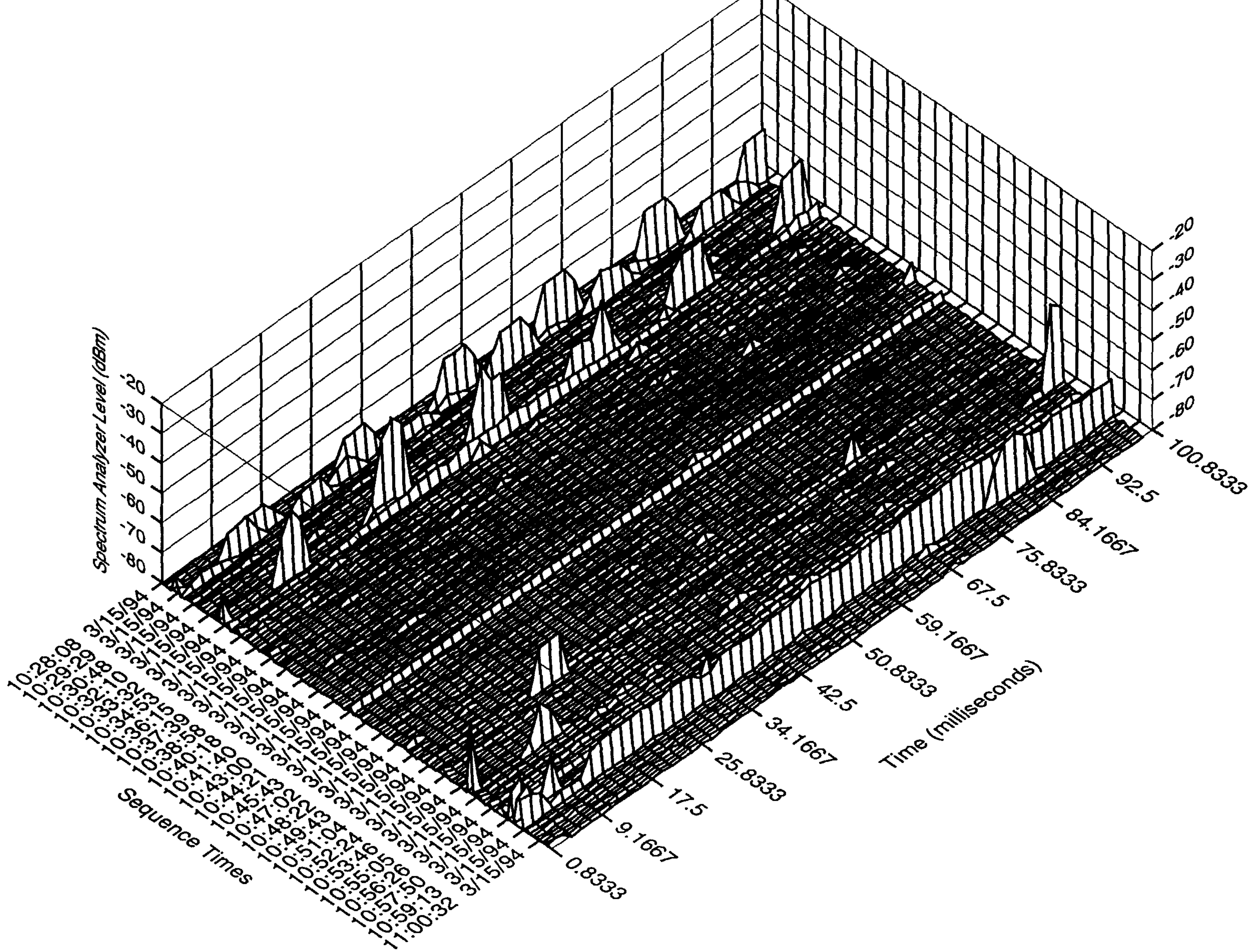


Figure ISM-2b

Lowest MSS Channel

Sequences 126-250

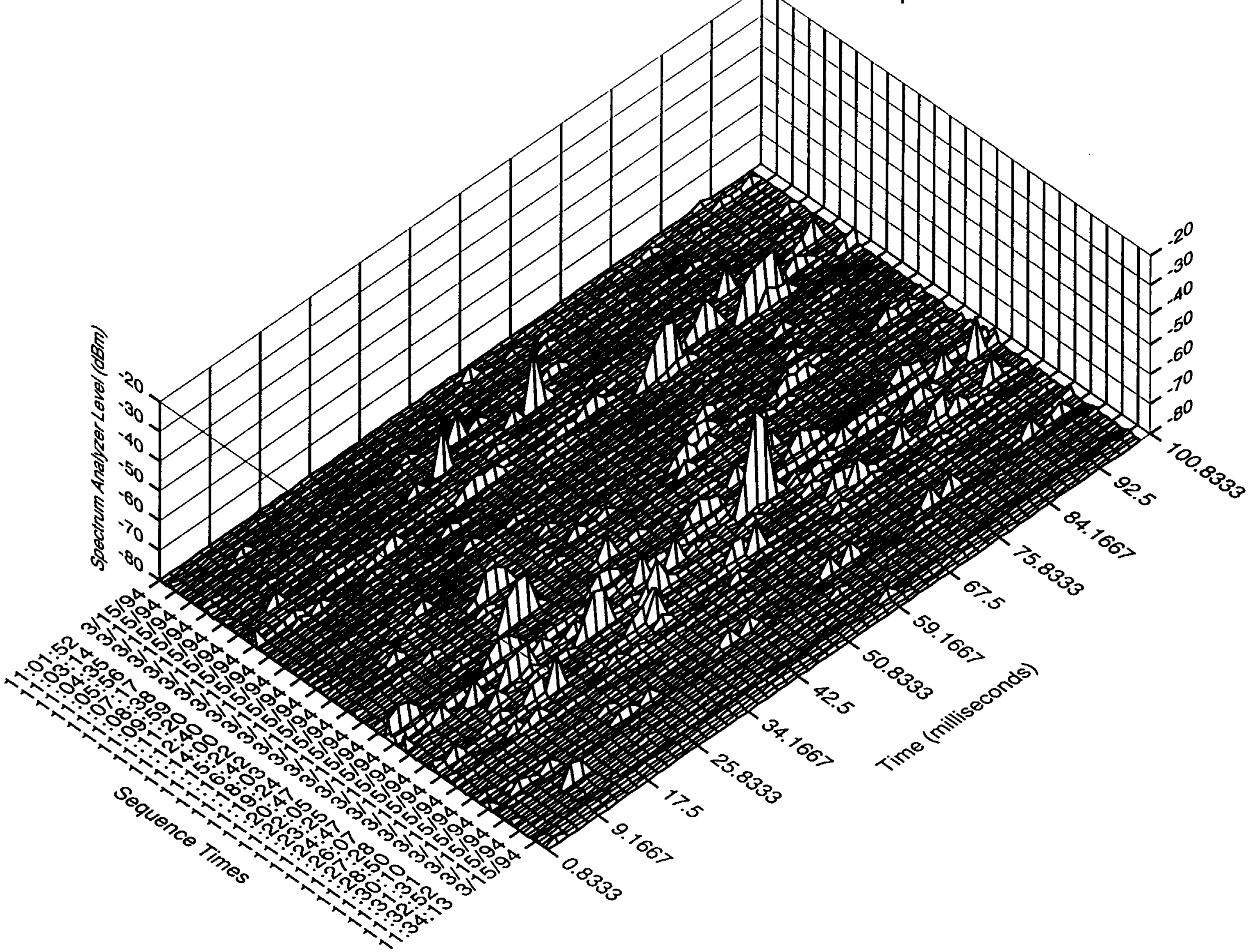


Figure ISM-2c

Lowest MSS Channel

Sequences 251-370

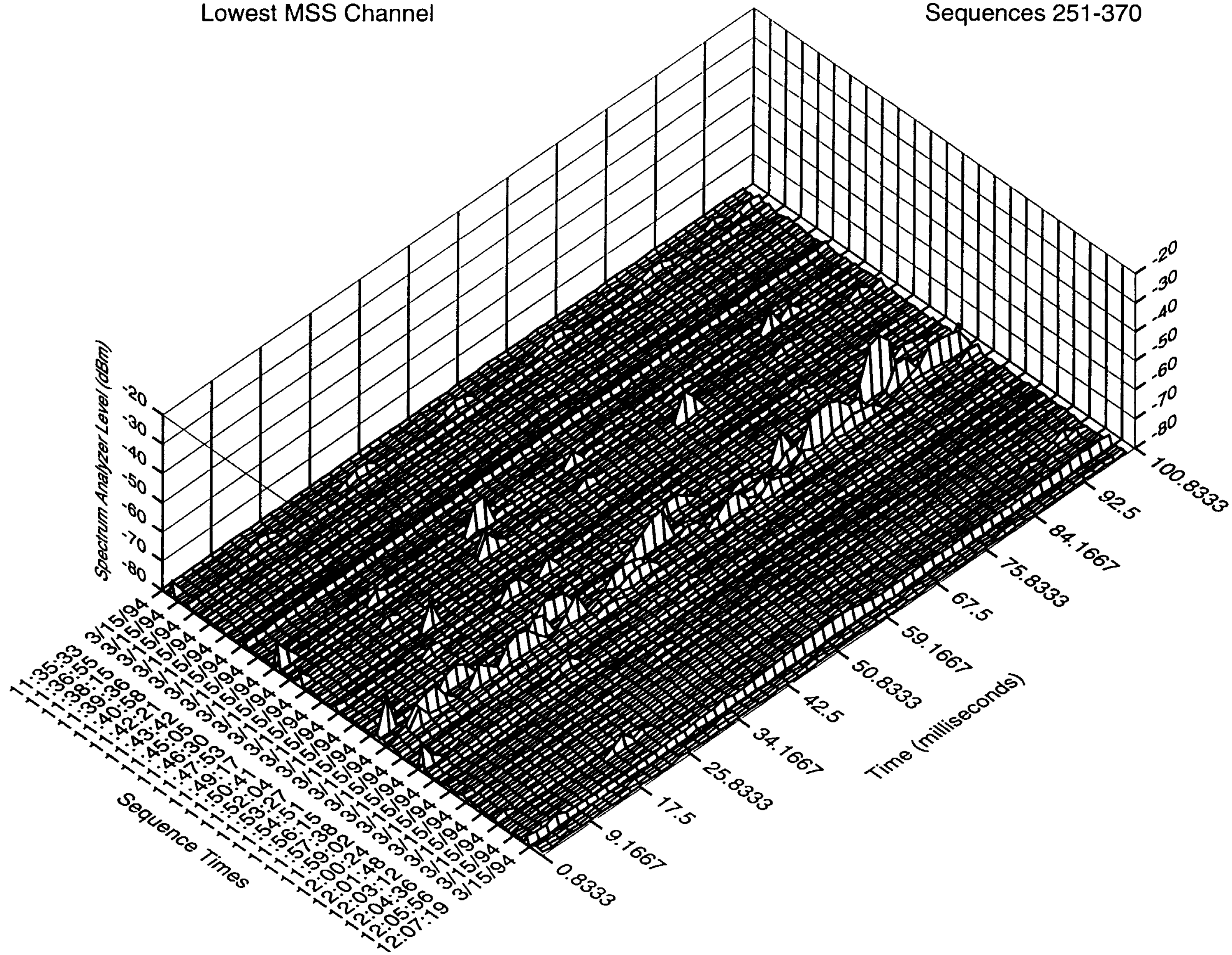


Figure ISM-2d

Lowest MSS Channel

Return Trip Set
Sequences 1-125

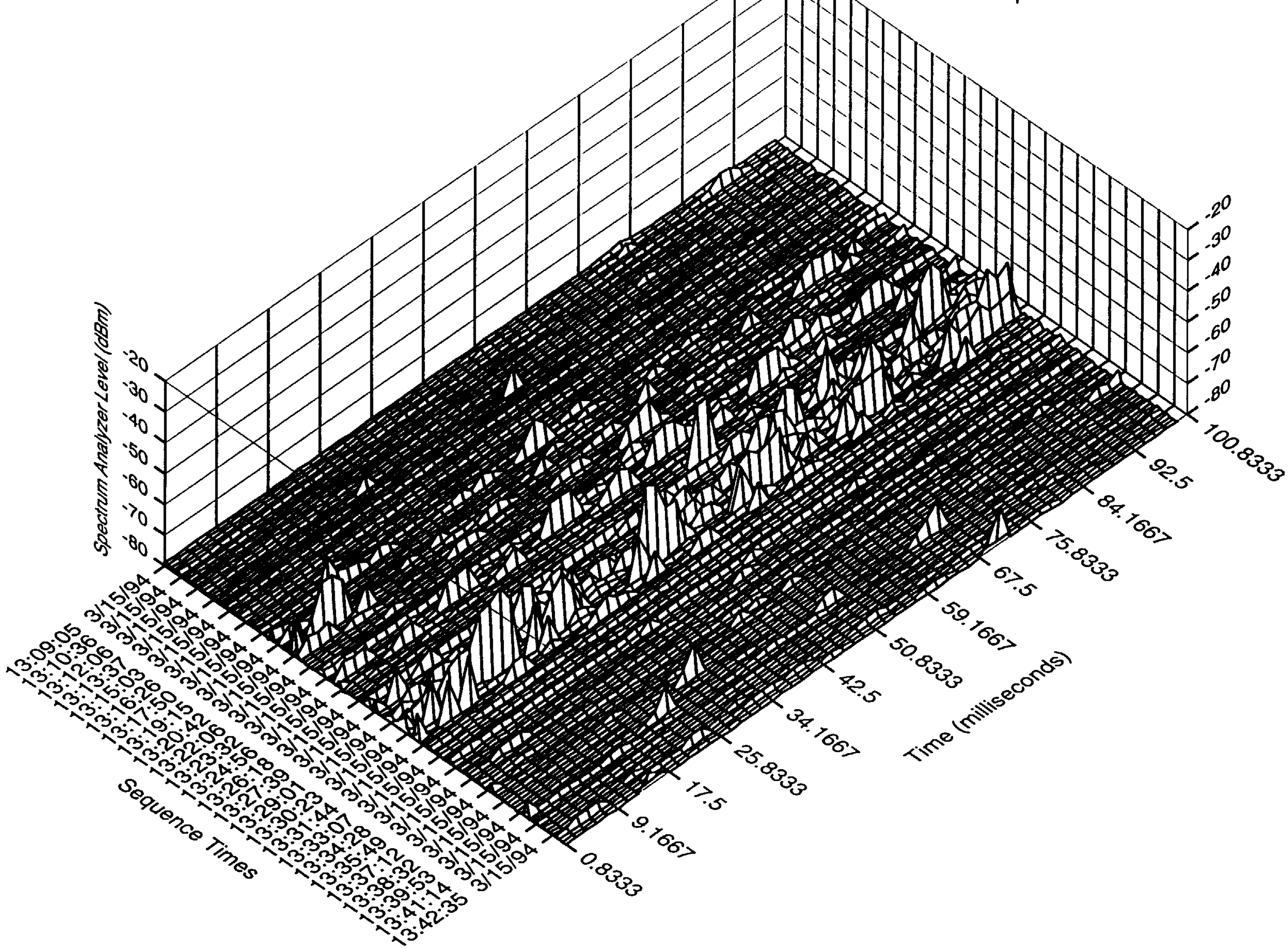


Figure ISM-2e

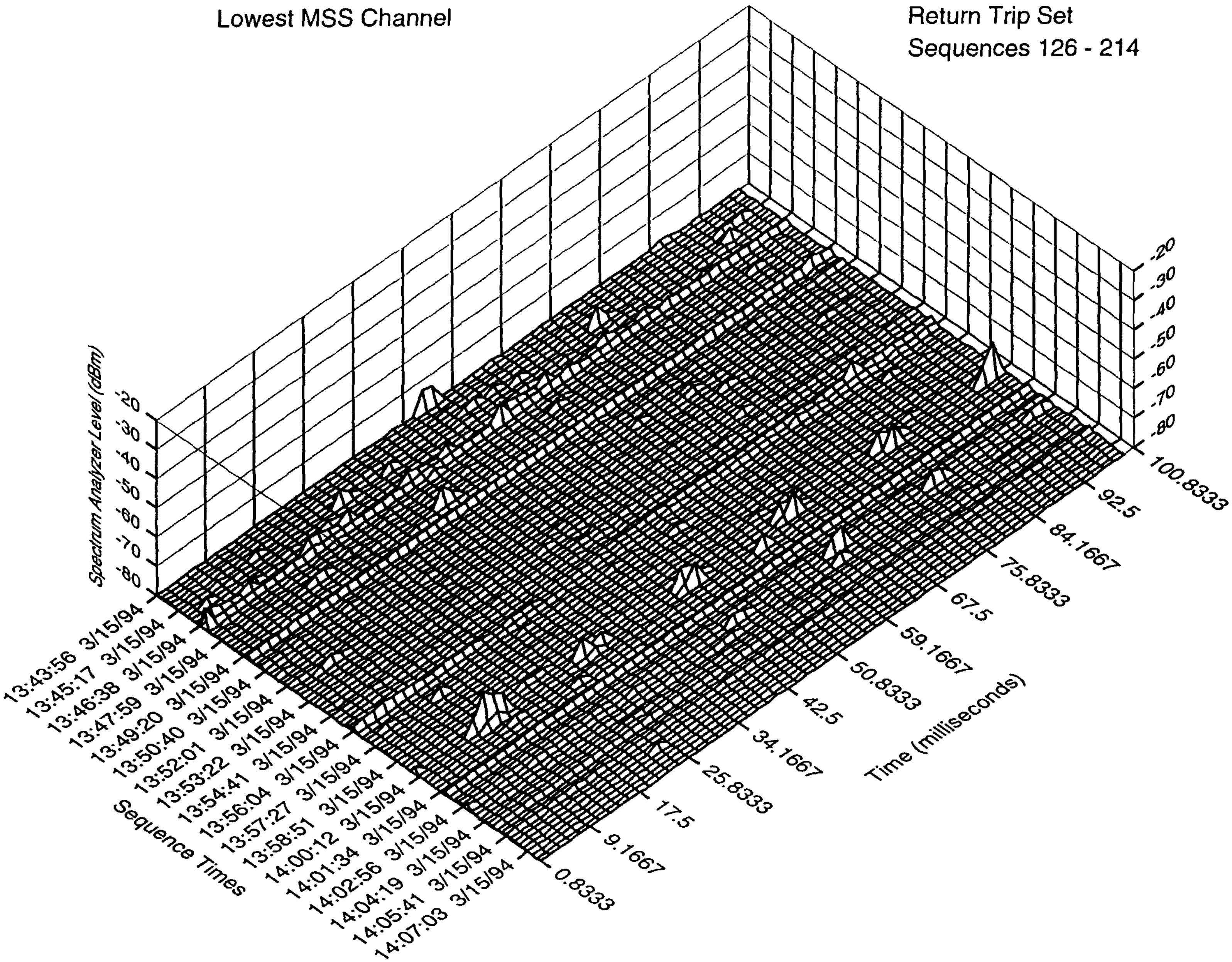
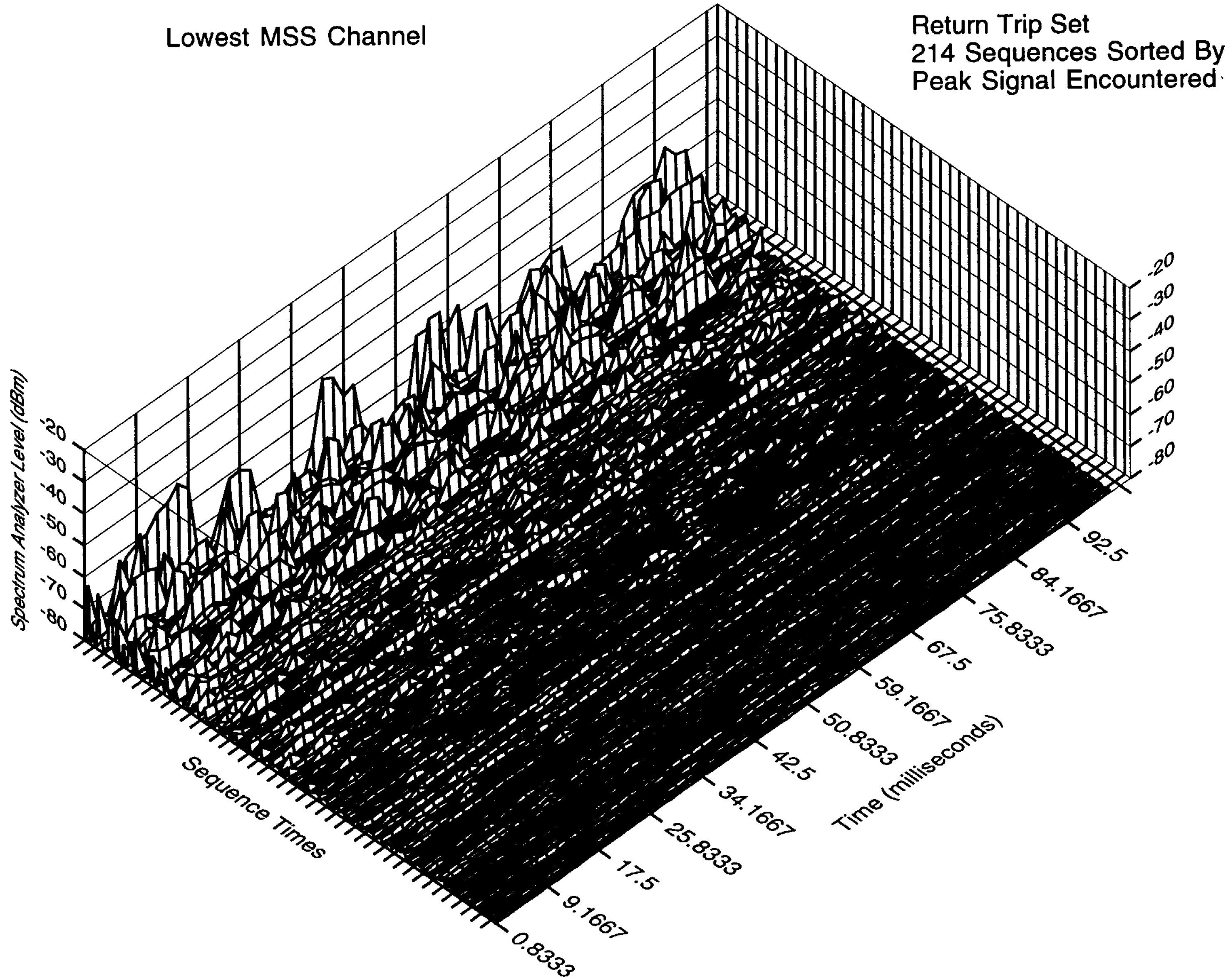


Figure ISM-3


Lowest MSS Channel
Return Trip Set
214 Sequences Sorted By
Peak Signal Encountered
Spectrum Analyzer Level (dBm)
-20
-30
-40
-50
-60
-70
-80
Sequence Times
Time (milliseconds)
0.8333
9.1667
17.5
25.8333
34.1667
42.5
50.8333
59.1667
67.5
75.8333
84.1667
92.5

Globalstar

Figure ISM-4

ISM Peak Measure

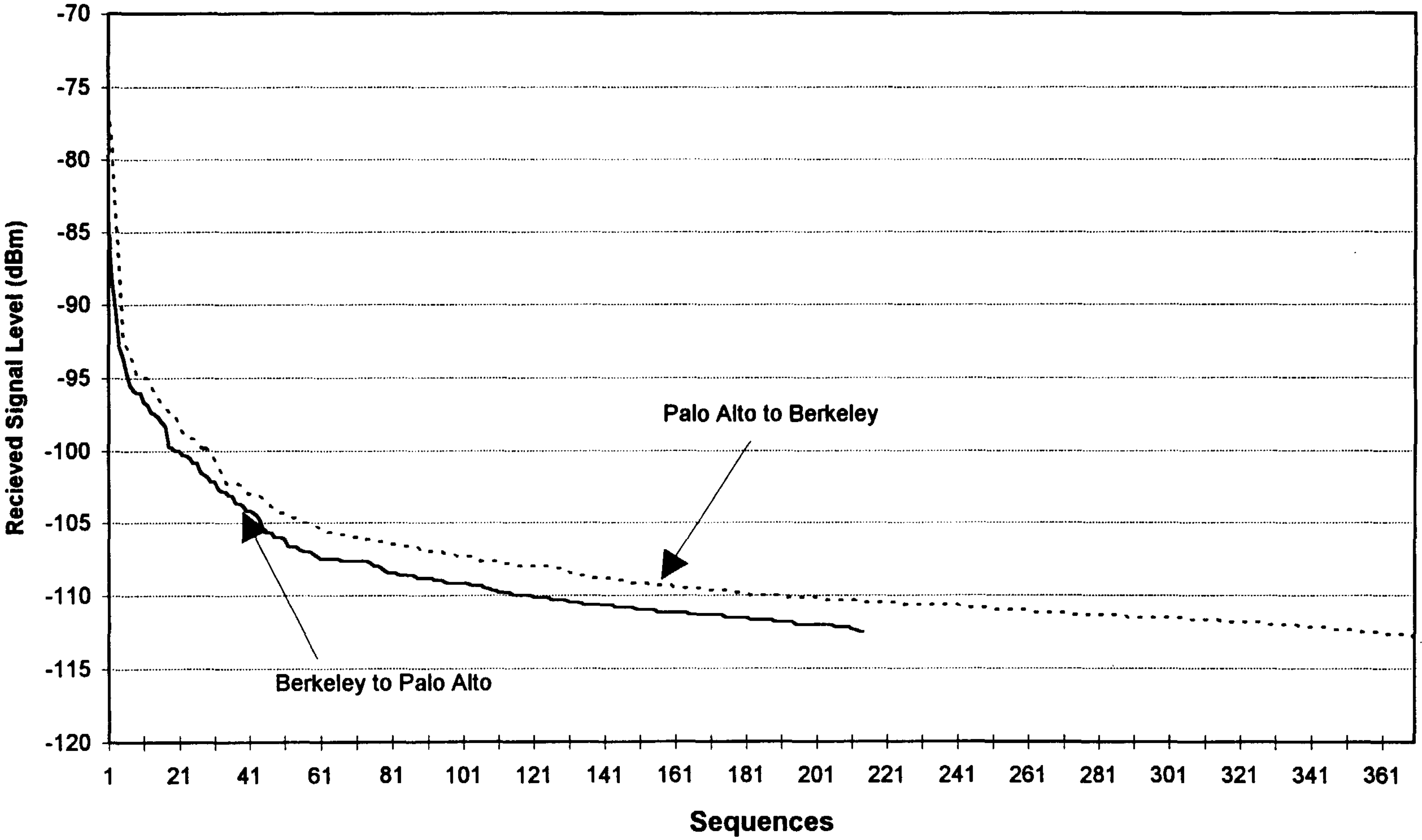


Figure ISM-5a
Histogram of CDMA Receiver Signal Exceedance By ISM Interference

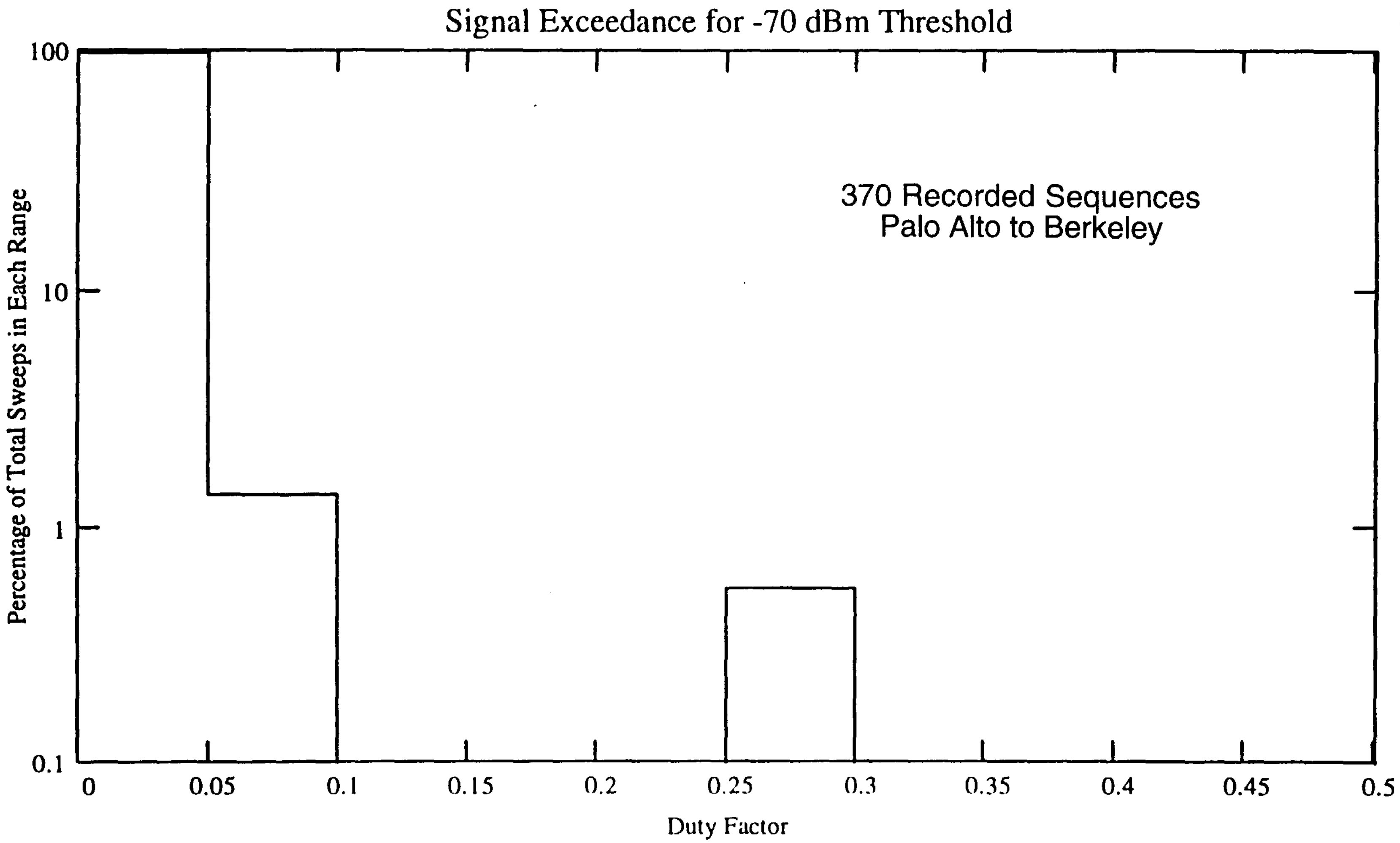
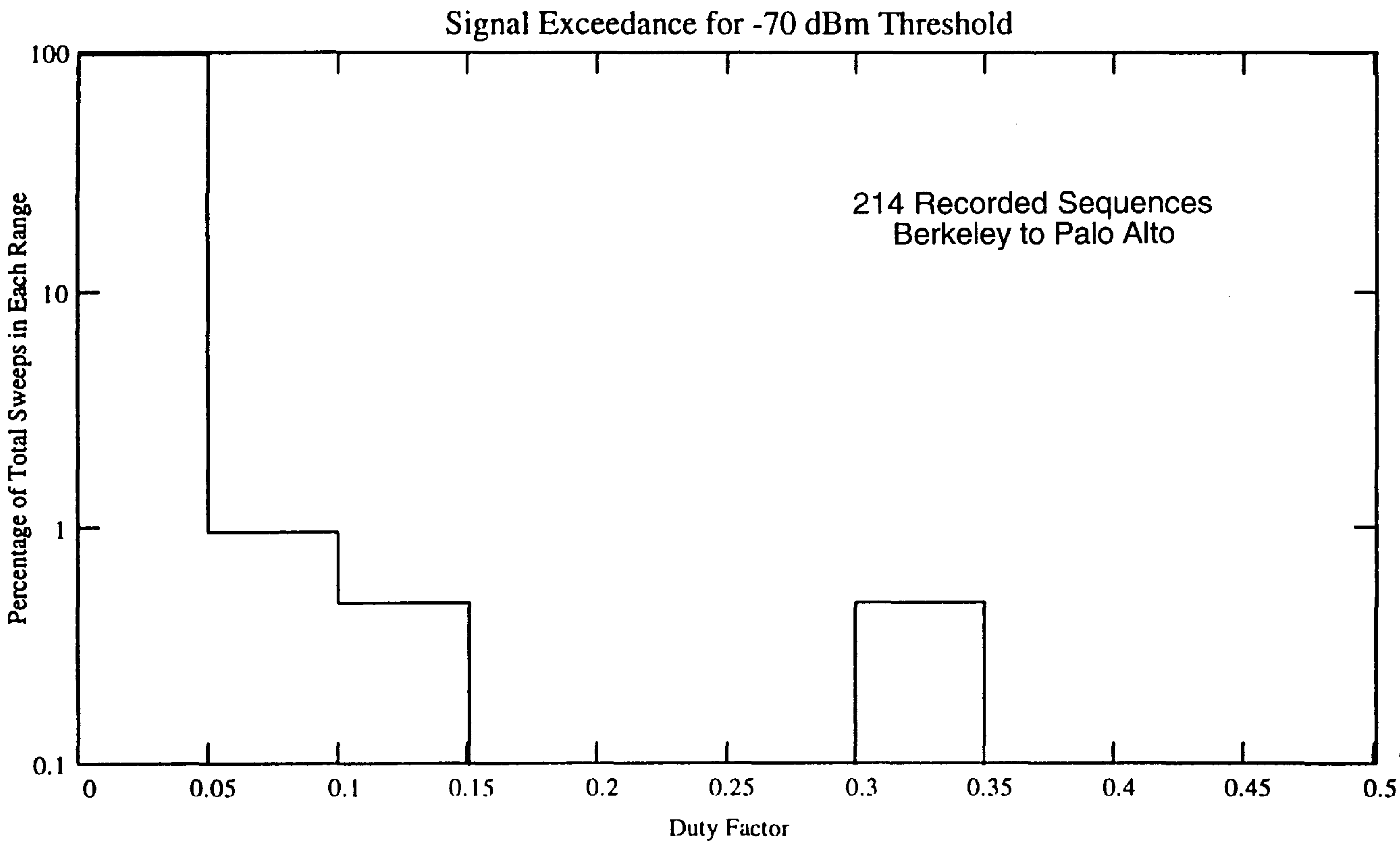


Figure ISM-5b
Histogram of CDMA Receiver Signal Exceedance By ISM Interference



5

ATTACHMENT 5

Discussion of ISM Measurements in the San Francisco Bay Area

1. General

Attachment A-4 describes a series of measurements of emissions from ISM equipment made recently by Globalstar in the San Francisco Bay area, a densely populated residential, industrial and commercial region. This Attachment discusses these tests and describes the conclusions that can be drawn regarding interference to operating MES from ISM equipments.

The measurements were made in a vehicle equipped with test equipment as it was driven from Loral facilities in Palo Alto in a large circle counterclockwise around San Francisco Bay, passing through or near major centers including Sunnyvale, Fremont, Oakland, Berkeley, San Francisco, South City, Burlingame, San Mateo, and Redwood City.

The outbound and return routes of the test vehicle are shown in Figure 1. Figures 2-6 depict the levels of emissions from ISM devices (and emissions from ITFS stations in the adjacent band beginning at 2500 MHz). Figure 2 plots the results of the first 125 sweep sequences on the outbound test run from Palo Alto. (One sweep sequence is a series of measurements of received power level over a range of frequencies. Each data point in the figures represents the maximum signal recorded in 23 sweeps over a two-minute period.)

This figure clearly shows both the concentration of emissions from ISM around 2450 MHz and the rapid fall-off of out-of-band emissions from the ITFS station in Berkeley, which occupies the lowest channel, "A-1," operating in the range 2500 - 2506 MHz. The consequence is a relatively interference-free band 2477 - 2500 MHz, a band encompassing the MSS space-to-Earth band that will be received by MES.

Figure 3, which plots the next 125 sequences, shows even more dramatically the relatively interference-free band to be used for MSS downlinks. The same conclusions can be drawn from Figures 4, 5, and 6, which plot the remaining 119 outbound sequences, and a total of 214 sequences on the return trip.

The effect on the lowest MSS channel, the one closest to the center of the ISM band, is shown in five figures in Attachment A-4. These figures summarize a total of 584 runs taken throughout the Bay Area over a period of about four hours. Note that interfering signals of any magnitude were detected only occasionally.

More significant than the rare incidence of the detection of emissions is their relatively low level. The highest of the instantaneous peak levels in the highest or the lowest MSS channel, as measured at the input to the spectrum analyzer is no more than about -50 dBm. Adjusting for the different antennas used by the measuring equipment and the MES, and the gain of a pre-amplifier in the measurement set-up. This level corresponds to a level of about -83.5 dBm. Unwanted signals above about -90 dBm would probably cause unacceptable interference, while levels of about -95 dBm would cause some degradation. However, the severity of interference does not depend only on the level of the peak interfering power. The use of CDMA modulation reduces the effect of individual interference spikes. Thus, the number and duration of interfering pulses from a particular oven must also be taken into account.